Regional Climate Messages for West Africa

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

ASSAR
Adaptation at Scale in Semi-Arid Regions

About ASSAR Working Papers

This series is based on work funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID) through the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA). CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The program supports collaborative research to inform adaptation policy and practice.

Titles in this series are intended to share initial findings and lessons from research and background studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the CARIAA program, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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Regional Climate Messages for West Africa

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SUMMARY MESSAGES

The climate across West Africa varies from arid to tropical monsoon conditions.

The region’s climate is mainly influenced by large scale seasonal atmospheric patterns and the warm waters of the tropical Atlantic Ocean. Temperatures are relatively high throughout the year and the majority of the region’s rainfall occurs in the summer months (April to September), whilst some coastal regions receive two peaks in rainfall.

Temperature and rainfall vary on annual, decadal and multi-decadal timescales.

Temperatures in the coastal regions do not vary much from year-to-year but there is more variation further north. Over the past half century there has been substantial multi-decadal variability in rainfall with prolonged dry periods. The 1980s were very dry and have been linked to the severe 1980s Sahel drought.

Temperatures across the region have increased by 1°C on average over the past 50 years.

The largest temperature increases have been observed in the March to May season, particularly in the northwest of the region (up to 3°C). Warming has been less pronounced in the summer months and some locations have cooled in the summer and winter seasons.

Future projections of temperature change show significant increases across the region.

Temperatures in the north of the region, from the Sahel to the Sahara, are projected to increase by at least 2°C on average by the 2040s with increases of over 3°C projected for some parts of the Sahara. Temperature projections are lower for southern coastal regions, where projected increases are between 1 and 2°C by the 2040s; however these still represent an acceleration of the warming compared to the recent past. Relatively high/low increases are more likely under a higher/lower greenhouse gas emissions scenario.

Rainfall trends over the past 50 years are less evident than for temperature, and there are large variations in the direction and magnitude of changes across the region.

There is evidence of a shift in the rainy season towards later rainfall for some regions. An increase in rainfall in some locations for some seasons is observed but a decrease in rainfall is observed elsewhere. In general, trends are weak.

Future model projections of rainfall contradict each other, showing both potentially large increases and decreases.

Projections of rainfall vary considerably. At present there is insufficient evidence to support either a shift to drier or wetter conditions in the future in most locations.

The impacts of future climate change on different sectors are complicated by the spread of model projections and the complexity of natural and societal systems.

The impacts of climate change on water resources and availability are unclear but the increased evaporation that is likely to occur with increased temperatures may place additional stress on vulnerable systems. Recent reviews of the literature state that despite no consensus on future precipitation trends, many studies predict the length of the rainy season to reduce in some parts of West Africa with implications for the agricultural sector.

CHAPTER 1

Historical Climate

Historical Climate

This report provides a general overview of the regional climate in West Africa. A follow-up report that provides a specific focus on the climate of the semi-arid regions of West Africa is currently under development.

1.1 General overview

The climate across West Africa varies from arid desert conditions in the north to humid tropical monsoon conditions along the coastal regions in the south. A semi-arid transect is located in the Sahel region, extending from northern Nigeria in the east to Senegal in the west. The primary factors affecting the climates experienced in West Africa include altitude, the proximity of the topical Atlantic Ocean, the migration of the Inter-Tropical Convergence Zone (ITCZ), and the location of dominant atmospheric high and low pressure systems. The West African monsoon affects much of the region; it is driven by the alternation of winds from dry northeasterly winds from the Sahara to southwesterly winds that bring moist air from the warm topical Atlantic Ocean.

Most of the region receives the majority of its rainfall in a single rainy season during the summer months (April to September) coinciding with the northerly migration of the ITCZ, with drier conditions in the winter months (October to March). However, some parts of the south, particularly the coastal regions of Ghana and Cote d'Ivoire, experience a two-peaked rainy season; a primary peak in rainfall occurs during May and June and a secondary peak occurs in September and October with relatively drier conditions between.

Temperatures across the region are relatively high throughout the year. In the southern coastal regions, there are very small differences in the average temperatures experienced throughout the year and the diurnal cycles are also relatively low; minimum temperatures are typically around 21°C and maximum temperatures are typically around 30°C. The highest temperatures are experienced in the Sahara desert in the north of the region. Here average maximum temperatures regularly exceed 40°C, though the variability throughout the year is larger than in the south with winter minimum temperatures often below 20°C. There are some mountainous areas in Guinea and parts of northern Nigeria, but very few places experience low temperatures.

1.2 Seasonal and annual variability

Throughout the year, the timing and magnitude of the summer rains is largely dictated by the seasonal migration of the ITCZ. This large-scale atmospheric feature represents an area of intense convective activity associated with low pressure. The ITCZ is found near the equator during late March and late September (the equinoxes) but moves north during the northern hemisphere summer bringing rains to much of the region. However, each year the amount of summer rainfall experienced varies as the ITCZ interacts with other dominant global and regional atmospheric patterns.

The best studied and arguably most important of these patterns is the El Niño Southern Oscillation (ENSO) – a cyclical variation in the surface temperature of the tropical eastern

Pacific Ocean. When the ocean surface in this region is warmer than average an El Niño event occurs and when the ocean surface is cooler than average a La Niña event occurs. The timing between ENSO events varies but typically an El Niño or La Niña occurs once every few years. The relationships between ENSO and the West African climate are fairly weak and any correlations are affected by limited data. Yet there is some evidence to suggest that an El Niño is associated with drier than normal conditions in West Africa while a La Niña is associated with cooler than normal conditions. There is also evidence that the West African monsoon is mostly influenced either during the developing phase of ENSO or during the decay of some long-lasting La Niña events (Joly and Voldoire 2009). However, the associations between ENSO and West African climate vary at small spatial scales and they are not always apparent. In general, the mechanisms that link ENSO and the West African climate are still not fully understood.

Year-to-year variability in the weather is a result of variability in these large scale processes and variability in regional and local scale processes, such as the African Easterly Jet (Camberlin et al 2001), as well as feedbacks between the atmosphere and land surface.

Figure 1.1

December to February (DJF) and June to August (JJA) mean, maximum and minimum temperatures at each grid cell over the period 1963 to 2012; adjacent grid cells may display warmest/coolest temperatures from different years. Data taken from the CRU TS3.22 dataset - see technical reference document.

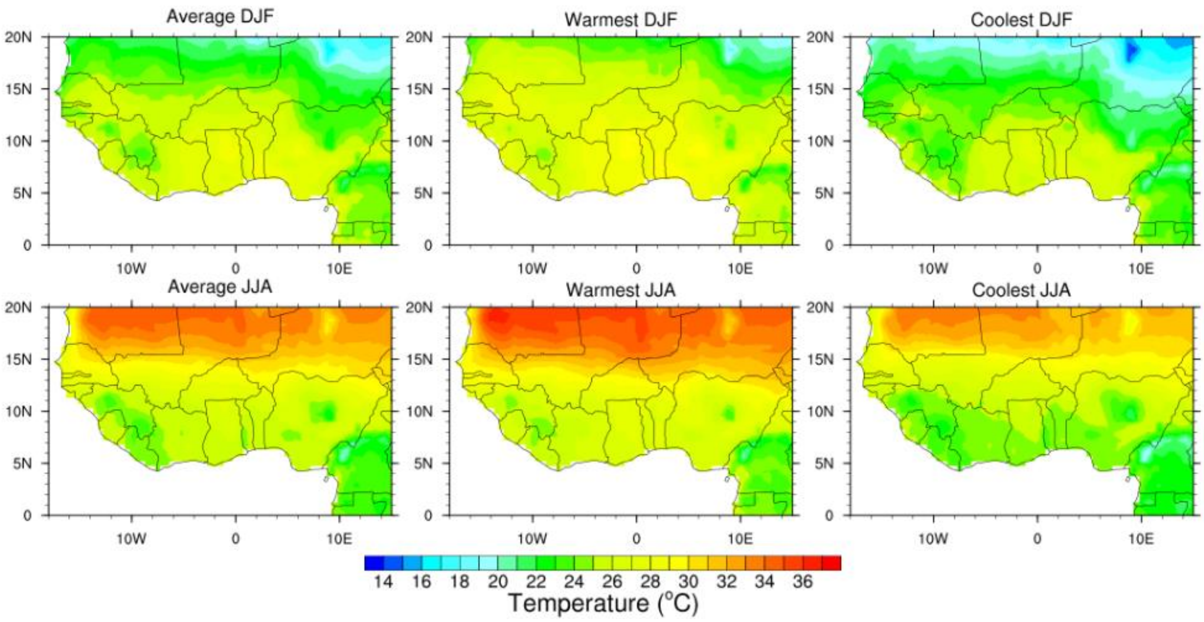


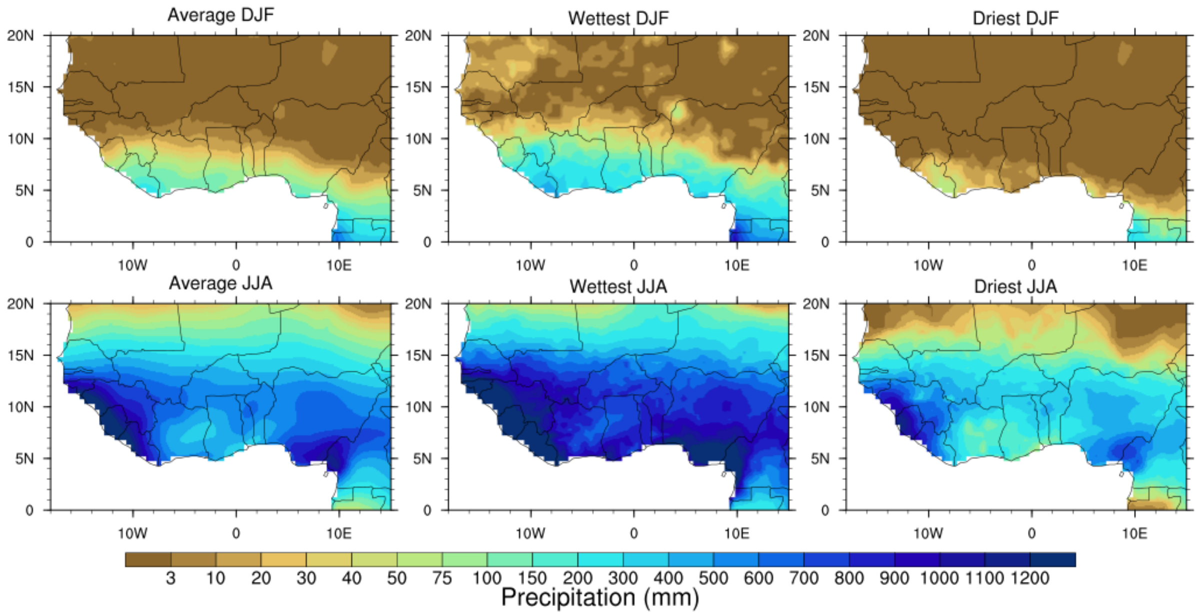
Figure 1.1 shows the average December to February (DJF) and June to August (JJA) temperatures across the region (left column), as well as the warmest (middle column) and coolest (right column) years over the 50 year period from 1963 to 2012 for a particular location; the year of the warmest/coolest season in one grid cell may differ for an adjacent grid cell. The figure shows that the whole region has relatively high temperatures. The highest summer (JJA) temperatures are experienced in the north of the region in the arid Sahara desert, where average temperatures can exceed 34°C. The coolest temperatures also

occur in the Sahara in the winter months (DJF), particularly in the eastern Sahara, as well as the higher altitude regions of northern Nigeria and, to a lesser extent, Guinea. The greatest differences between the average winter and summer temperatures in the warmest and coolest years are also found in the northern regions, with very low variability in the southern coastal regions.

Rainfall is considerably more variable than temperature, both in space and time. Figure 1.2 shows the average winter and summer rainfall as well as the wettest and driest years at each grid cell. In winter there is essentially no rainfall in the north of the region, though some parts in the northwest can receive up to 30 or 40mm rainfall in the wettest years. Further south, between 50 and 200mm of rainfall is accumulated during the winter, with some coastal regions experiencing many hundreds of millimeters in the wettest years and almost no rainfall in the driest years. The region receives the majority of its rainfall in the summer. There is a strong gradient along the Sahel region and considerable differences between the wettest and driest years. For example, in northern Burkina Faso over 500mm of rainfall occurs during the wettest summers while less than 200mm of rainfall falls in the driest summers.

Figure 1.2

December to February (DJF) and June to August (JJA) mean, maximum and minimum total rainfall at each grid cell over the period 1963 to 2012; adjacent grid cells may display wettest/driest conditions from different years. Data taken from the CRU TS3.22 dataset – see technical reference document.



1.3 Decadal and longer term variability

The climate of West Africa also varies on much longer time scales. Decadal and longer term variability in the climate system results from natural processes both internal and external to the climate system. On decadal, multi-decadal and centennial time scales, major modes of variability are found in the Pacific, Atlantic, Indian and Southern Oceans, and they can have substantial influences on global and regional atmospheric circulation patterns. These large scale modes of natural variability mean that one decade can be warmer or cooler, and drier or wetter than the previous decade without any changes in the external influences on the climate system. However, factors such as solar cycles, volcanic eruptions, biosphere processes, and more recently human emissions of greenhouse gases (GHGs) and aerosols (particulates in the atmosphere), exert external forcings on the climate system that can also cause variability and change on long time scales.

Figure 1.3 shows the difference between the mean decadal (ten year) temperature and the mean temperature over the 1963 to 2012 period at each grid cell. We can clearly detect a warming signal as all locations in West Africa were warmer, on average, in the 2000s than in the 1970s. The 2000s were particularly warm in the northern part of the region with parts of Mali and Mauritania at least 1.5°C warmer in the 2000s compared to the 1970s. However, it is also apparent that in some locations more recent decades have been cooler than preceding decades; for example, Togo, Benin, western Nigeria and southern Mali were all warmer in the 1980s than in the 1990s.

Figure 1.3

Difference between decadal mean temperatures and 1963 to 2012 mean temperatures at each grid cell. Data taken from the CRU TS3.22 dataset – see technical reference document.

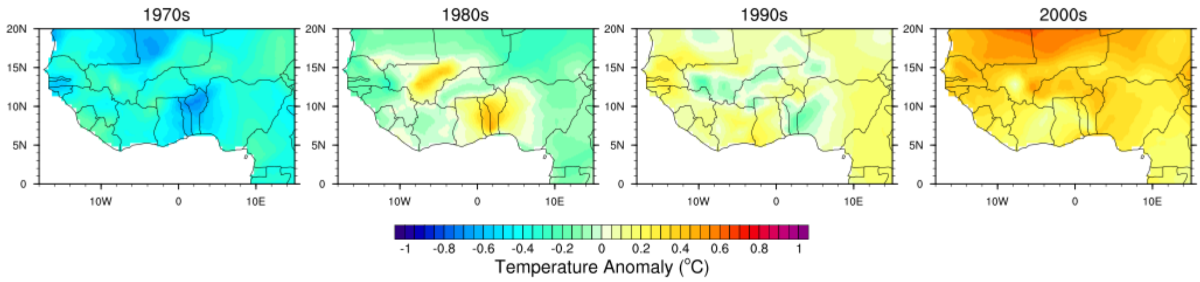
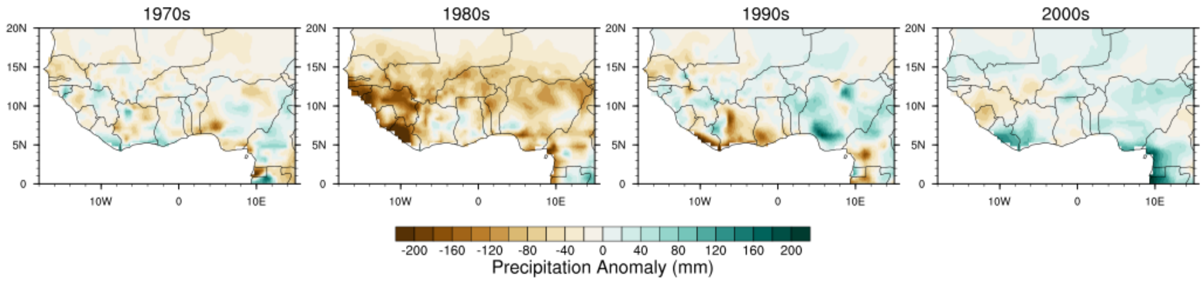


Figure 1.4 shows the difference between the mean annual rainfall total for each decade and the mean annual rainfall total over the 1963 to 2012 period at each grid cell, illustrating considerable variability in rainfall on multi-decadal time scales. The figure shows that the 1980s was a particularly dry decade for much of the region, which coincides with Sahel Drought (Nicholson 2013) that caused considerable hardship to communities across the region (Brooks 2004). By contrast, the 2000s were slightly wetter for much of the region, with the exception of Guinea, Sierra Leone, southern Mali and southern Ghana.

Figure 1.4

Difference between decadal mean annual rainfall totals and 1963 to 2012 mean annual rainfall totals for each grid cell. Data taken from the CRU TS3.22 dataset – see technical reference document.



On much longer time scales, the climate can vary dramatically due to external influences on the climate system. Over time scales of thousands of years, it is well established that the glacial-interglacial cycle is primarily driven by variations in the orbit, tilt and precession of the Earth and the resultant impact on incoming solar radiation.

1.4 Climate trends

To determine whether or not, and by how much, the climate has changed in the recent past, trends in temperature and rainfall are calculated from the available observed data. Figures 1.5 and 1.6 show the seasonally averaged spatial and temporal changes in temperature over West Africa during the period 1963 to 2012. Despite annual and decadal variability, across all seasons and locations temperatures have increased over this period, with the exceptions of some localized cooling in the border region between Burkina Faso, Ghana and Cote D'Ivoire as well as the northeast region of Niger during winter, and southern Mali in summer. Averaged across the whole region and all seasons, temperatures in West Africa have increased by approximately 1°C over the past 50 years. Temperature increases were generally higher (0.6 to 3.0°C) in northern parts of the region, particularly in Mali and Mauritania in spring (MAM), and lower (0.4 to 1.4°C) along the coastal regions of West Africa. Whilst there has been an increase in temperatures in most locations in all seasons, the highest increases are found in the spring and autumn (SON) seasons; note that Senegal also shows large increases (over 1.5°C) in winter.

Figure 1.5

The change in temperature between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: DJF, MAM, JJA and SON. Data taken from the CRU TS3.22 dataset – see technical reference document.

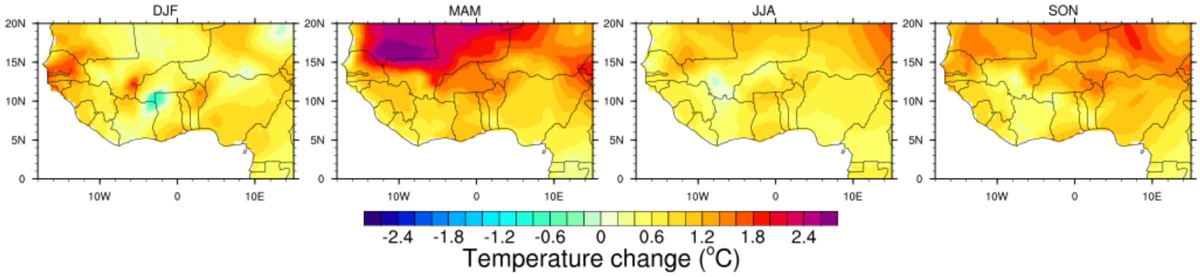
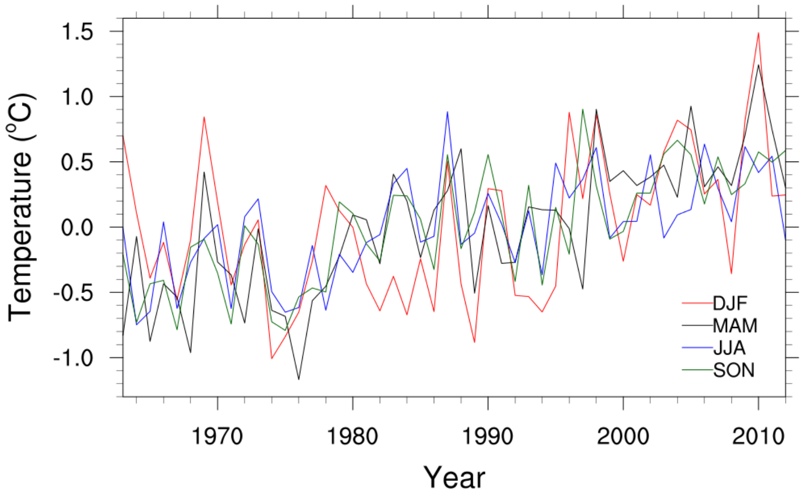


Figure 1.6

Time series of the land area averaged seasonal temperature changes between 1963 and 2012, corresponding to figure 5. Data taken from the CRU TS3.22 dataset – see technical reference document.



Figures 1.7 shows the change in total rainfall for each season from 1963 to 2012. There appears to have been a shift in the rainy season along large stretches of the coastline, with decreased rainfall in spring and summer but increased rainfall in autumn. However, along western parts of the coastline, from Liberia to Senegal, there has been no increase in autumn. Further north, the signals are mixed with seasonal increases and decreases evident in different regions. During the dry winter season, there is a weak signal of drying in southern parts of the region. Crucially, the patterns of change are not consistent everywhere and rainfall in West Africa, as described in prior sections, is highly variable so any signals of systematic change need to be assessed for significance.

Observations of rainfall are subject to substantial uncertainty – see technical reference document. Therefore the evidence presented here must be treated with caution and the conclusions must be interrogated in the context of additional regional and local scale information and observed datasets. In particular, linear trends in rainfall are not entirely reliable as an indicator of change, especially in semi-arid regions where year-to-year variability is high. Figure 1.8 shows the variation in annual rainfall at two locations in Burkina Faso and Senegal. The year-to-year variability is especially high for Thies in Senegal where some years receive at least twice the amount of rainfall experienced in other years. Both stations are located in semi-arid regions, though Ouagadougou is on the southern edge of the semi-arid zone in Burkina Faso. The evidence supports a general observation that drier locations are typically associated with higher year-to-year rainfall variability.

Figure 1.7

The change in rainfall between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: DJF, MAM, JJA and SON. Data taken from the CRU TS3.22 dataset – see technical reference document.

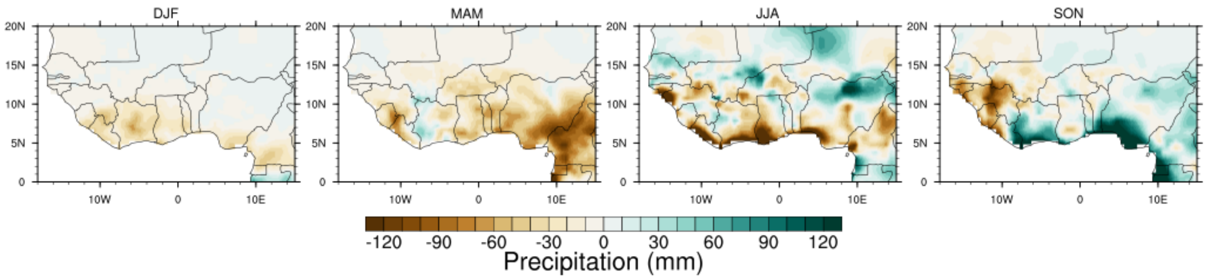
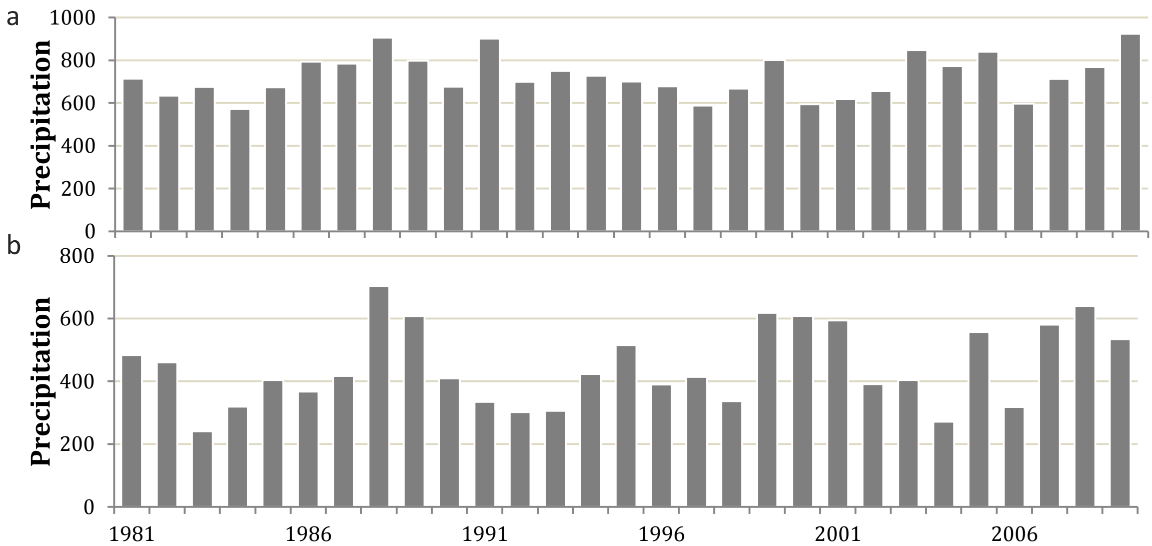


Figure 1.8

Station observed annual rainfall (mm) at: a) Ouagadougou, Burkina Faso, and b) Thies, Senegal. Data extracted from the CSAG Climate Information Platform; 1981 to 2009 represents the longest period of concurrent, uninterrupted observations.



In relating any observed climate trend to underlying changes in the climate, we must first account for the different time scales of climatic variability. In West Africa, the climate is subject to decadal and longer term climate variability (see section 1.3). Moreover, even if we detect a significant trend, that we are confident is not merely a result of long time scale variability, we must first rule out other external drivers before we can attribute such changes to increasing GHG concentrations – see technical reference document for more explanation.

1.5 Trends in extreme rainfall and temperature

To better understand the impacts of historical climate variability and future climate change on communities and ecosystems, it is often more relevant to focus on the less frequent but more severe weather and climate events that influence exposure and vulnerability.

A report by Climate Development Knowledge Network (CDKN 2012) summarizes the findings of the Intergovernmental Panel on Climate Change (IPCC) special report on managing extreme events (SREX, IPCC 2012). Changes to temperature and precipitation extremes in West Africa observed since the 1950s, with the period 1961-1990 used as a baseline, are reported (see Box 3.1 in Chapter 3 of SREX for more information):

- Significant increase in temperature of warmest day and coolest day in large parts – *medium confidence*
- Increasing frequency of warm nights, decrease in cold nights in large parts – *medium confidence*
- Precipitation from heavy rainfall events decreased in many areas (low spatial coherence), rainfall intensity increased – *medium confidence*
- Increased dry spell duration, greater inter-annual variation in recent years – *medium confidence*

Because of sparse and unreliable observations across much of West Africa, and given statistical issues associated with deriving trends in extremes for short sampling periods, none of the findings are stated with high confidence. Also, there is an apparent contradiction in the statement on heavy rainfall as the report states that many areas have seen a decrease in the amount of rainfall received in heavy rainfall events, while stating that rainfall intensity has increased. Furthermore, the report states that there is insufficient evidence to say anything meaningful about trends in heatwaves. This makes any analysis of the impacts of climate change on extreme weather, and the resultant consequences for society, very difficult.

An earlier study by New et al (2006) analyzed daily temperature (maximum and minimum) and precipitation data from 14 south and west African countries over the period 1961–2000. The findings of the study are largely consistent with the SREX results but the study also showed evidence of increase in dry spell durations and rainfall intensity. However, the observed trends in temperature extremes were more apparent than for precipitation. Furthermore, the authors provided evidence that the frequency of hot extreme events had been increasing at a faster rate than the decrease in cold extreme events, resulting in the conclusion:

"Hot extremes generally have trends of greater magnitude than their cold counterparts, suggesting that the warm tails of the daily temperature distributions are changing faster than the cold tails." (New et al 2006)

CHAPTER 2

Future Climate Projections

Future Climate Projections

2.1 Key results in the IPCC AR5

Climate change projections span a range of possible future climates. This range results from substantial uncertainty in key climate processes as well as different future GHG emissions scenarios. The projections shown in this section are taken from the available output of the latest generation of Global Climate Model (GCM) experiments. It is possible that the "true" uncertainty range is wider than the range of model projections. Further information on the issues associated with climate prediction is provided in the supporting reference document.

The IPCC fifth assessment report (AR5) provides a synthesis of the output from approximately 40 GCMs developed at institutions across the world. The model simulations were conducted as part of the fifth phase of the Coupled Model Intercomparison Project (CMIP5)[1] to generate a set of climate projections for the coming century. This section presents some of the model results relevant for West Africa.

Globally, average annual temperatures are projected to rise by 0.3 to 2.5°C by 2050, relative to the 1985 to 2005 average, but projected changes are higher for land areas. Figure 2.1 shows that in West Africa temperature projections range from a change of approximately -0.5 to +4°C in winter and from 0 to +3.5°C in summer by 2050. Lower temperature increases are more likely under a low emissions scenario and higher temperature increases are more likely under a high emissions scenario.

[1] http://cmip-pcmdi.llnl.gov/cmip5/

Figure 2.1

Time series of temperature change relative to 1986–2005 averaged over land grid points in West Africa in December to February (left) and June to August (right). Thin lines denote one model simulation and thick lines are the multi-model mean. On the right the 5th, 25th, 50th, 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2081–2100 for the four RCP scenarios. Source: IPCC (2013).

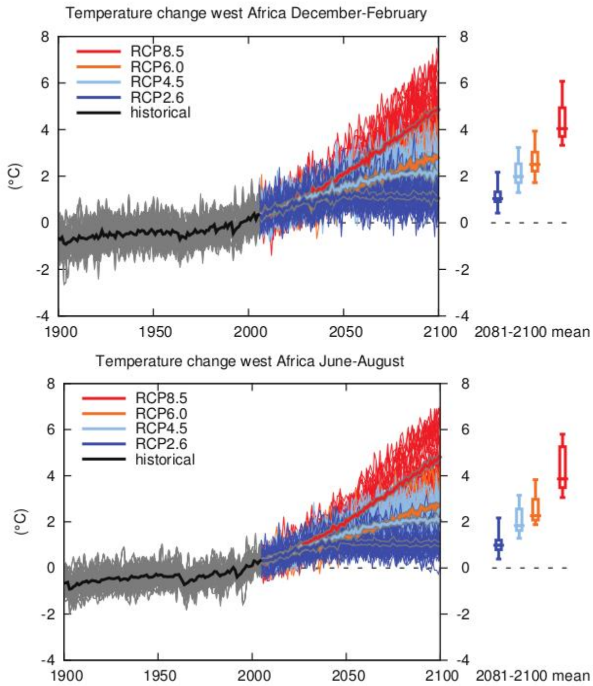
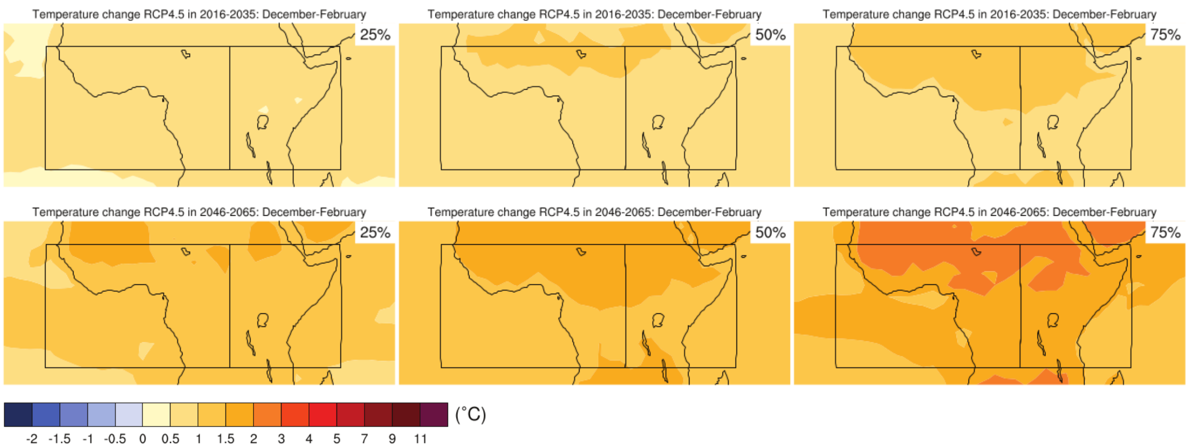


Figure 2.2

Maps of temperature change in West Africa in December to February for 2016–2035 and 2046–2065 with respect to 1986–2005 according to the RCP4.5 scenario. The left column show the 25th percentile (i.e. a quarter of models are below these values), the middle column shows the median and the right columns shows the 75th percentile (i.e. a quarter of models are above these values). Source: IPCC (2013).

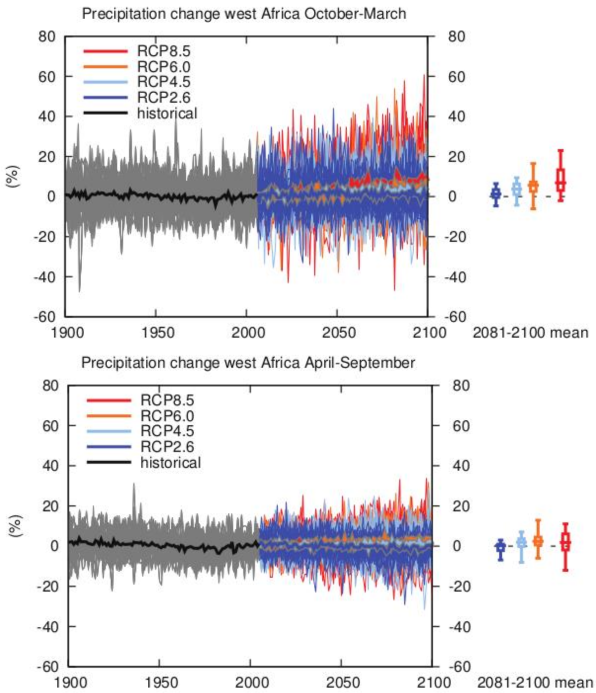


Projected changes in temperature vary spatially. Figure 2.2 shows that, for the RCP4.5 emissions scenario, northern regions of West Africa are projected to warm more than other regions, continuing the observed trends shown in section 1.4. The figure shows that by mid-century half of all model simulations project a warming in winter of between 2 and 3°C for northern regions of West Africa and between 1 and 2°C for southern regions of West Africa. In the summer season (not shown), the spatial pattern is broadly similar but the magnitudes of change are slightly less than those projected for the winter. Beyond increases in average temperatures, the IPCC report states “it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase”.

Future projections of rainfall change are subject to substantial uncertainties and model simulations disagree on the likely direction and magnitude of change. In West Africa, variability on interannual, decadal and multi-decadal time scales, as experienced in the past, is expected to continue to be the dominant influence on future rainfall. However, towards the end of the 21st century there is a tendency of some models to predict a shift to slightly wetter conditions on average over West Africa in October to March, especially for the high RCP8.5 emissions scenario. Figure 2.4 shows this shift to slightly wetter conditions in October to March, with some models predicting an average increase across the region of over 20% under the RCP8.5 emissions scenario. However, for the next few decades up to 2050 any signal across the model ensemble remains either weak or non-existent.

Figure 2.4

Time series of precipitation change relative to 1986–2005 averaged over land grid points in West Africa in October to March (left) and April to September (right). Source: IPCC (2013).



2.2 CORDEX Projections

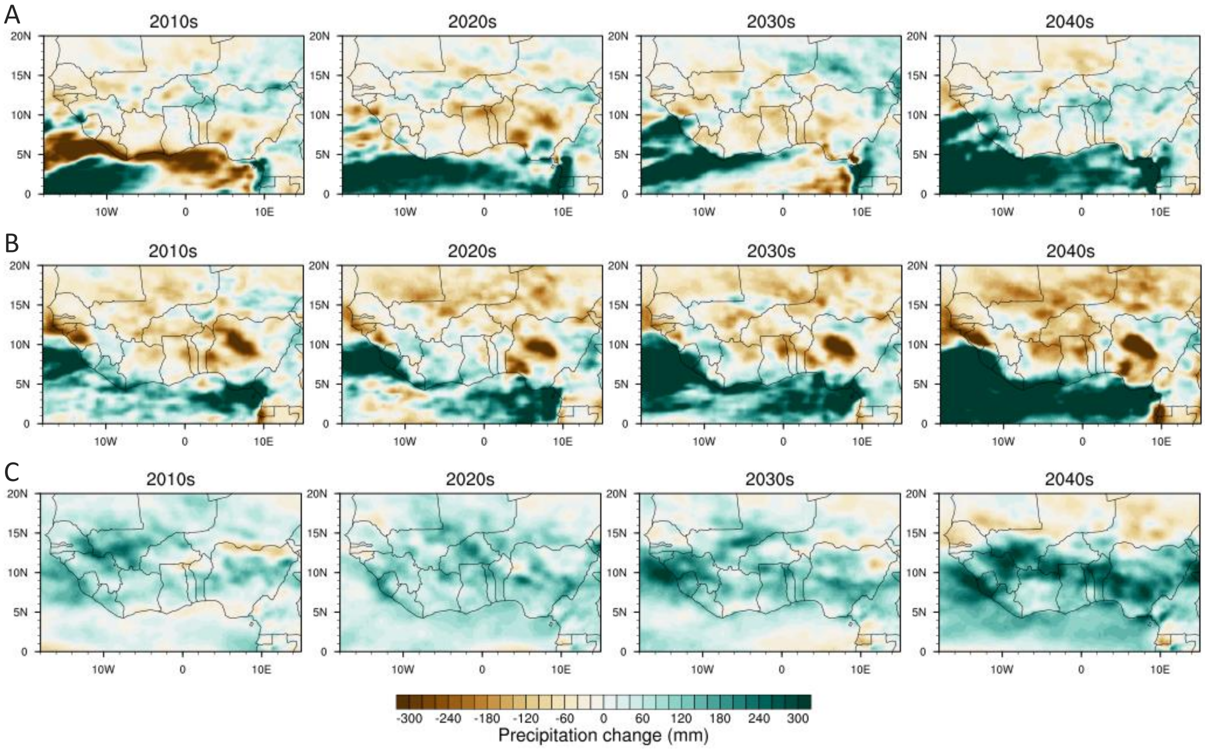
The Coordinated Regional Downscaling Experiment (CORDEX) uses the latest generation of regional climate models (RCMs) to provide 50 km resolution projections of climate change up to the year 2100 for regions across the world. The models are driven by GCMs used in the IPCC AR5 report. Here, some example CORDEX model projections are presented showing possible future regional climate change scenarios for West Africa. It should be noted that all projections shown are for the same GHG forcing scenario, RCP8.5; this scenario is often categorized as “business as usual” with respect to GHG emissions.

Regional climate projections are subject to significant uncertainties (Hawkins and Sutton 2009). The output of a single model simulation should be treated with caution and even an ensemble of regional model projections cannot be expected to provide reliable quantitative “predictions” (Daron et al 2014). Rather, the projections show possible scenarios of future change. Further explanation of the issues in projecting the future climate at regional scales is provided in the supporting technical reference document.

The model projections shown in figure 2.5 are taken from combinations of two GCMs (HadGem2 and ICHEC) and two RCMs (KNMI and CCLM4), all driven by the RCP8.5 scenario. A more rigorous exploration of future climate scenarios would involve analyzing many more GCM-RCM combinations that are being made available in the CORDEX project. However, for demonstrative purposes it is useful to look at some of the available data to examine the nature of future climate output. Figure 2.5 shows model projections of future rainfall change for four decades. The average annual rainfall change for a particular decade is calculated by subtracting the decadal average from the average annual rainfall over the period 1950 to 2000 in the model. The model projections indicate very different responses of the regional climate for the selected future GHG forcing scenario. Model C projects wetting across the region with some central regions projected to have up to 300mm more rainfall by the 2040s. This contrasts considerably with the Model A and Model B projections, which use a different RCM. Over land the climate change signals from these projections are mixed. However, model B suggests considerable drying in Senegal, Guinea and central regions of Nigeria. Over the ocean both of these projections show very large increases (over 300mm) in the annual average rainfall; the only exception is in model A where the ocean closer to the land is projected to become drier in the 2010s.

Figure 2.5

Difference between decadal mean annual rainfall totals and the 1950 to 2000 mean annual rainfall totals, at each grid cell, for three CORDEX models under the RCP8.5 scenario: A = HadGem2-CCLM4; B = ICHEC-CCLM4; and C = ICHEC-KNMI.



Even with the output of only three model simulations, there is no consensus on the direction of change in rainfall for the future. There is, however, much better agreement that temperatures are likely to increase. Figure 2.6 shows decadal changes in temperature for the same set of GCM-RCM combinations under the RCP8.5 scenario. In all model simulations, temperatures across the region are projected to rise. There is greater warming in the north, which corroborates with the CMIP5 GCM projections and the observed warming experienced in the last 50 years (see sections 1.4 and 2.1). Model A projects the greatest magnitude increase by the 2040s with mean temperatures projected to increase by up to 3°C across the Sahel and above 3°C in the Sahara. For the southern coastal part of the region, temperatures are projected to increase by at least 2°C by the 2040s, which represents a dramatic acceleration of temperature increases compared to the historical record. The changes are smaller in model B and C but all areas are projected to warm by at least 1°C by the 2030s and 1.5°C by the 2040s.

Figure 2.6

Difference between decadal mean temperatures and the 1950 to 2000 mean temperatures, at each grid cell, for three CORDEX models under the RCP8.5 scenario: A = HadGem2-CCLM4; B = ICHEC-CCLM4; and C = ICHEC-KNMI.

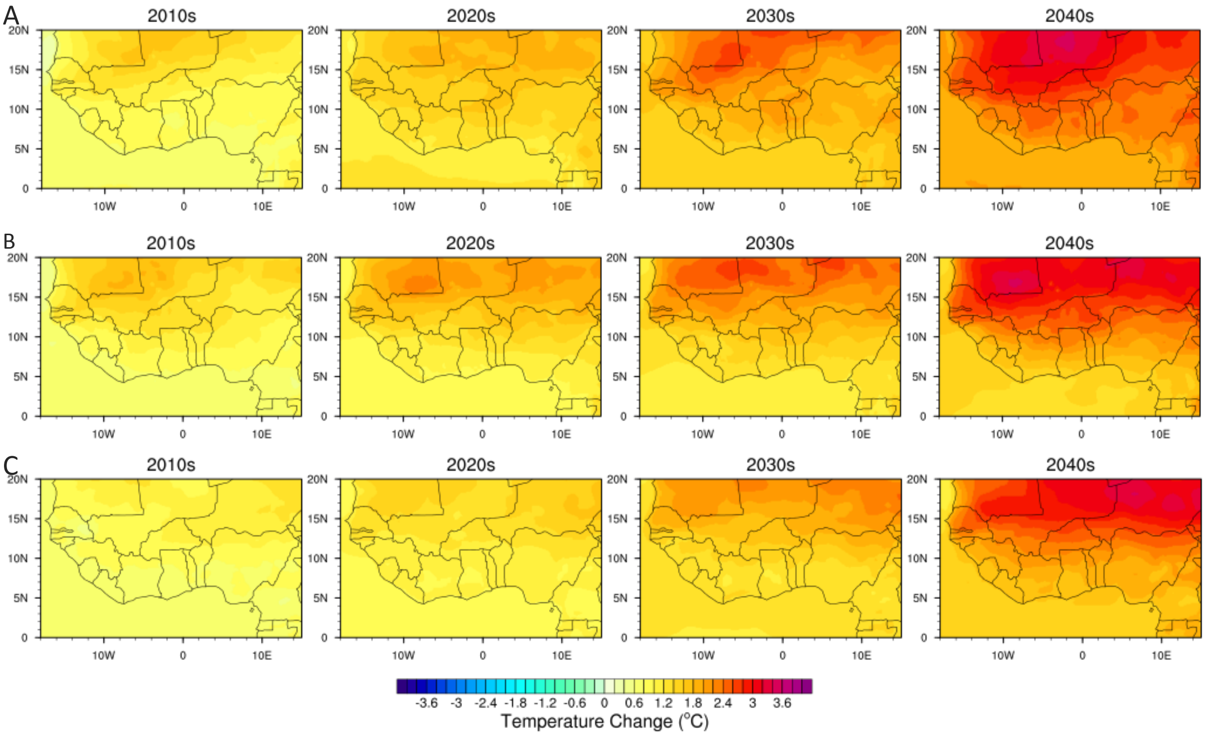
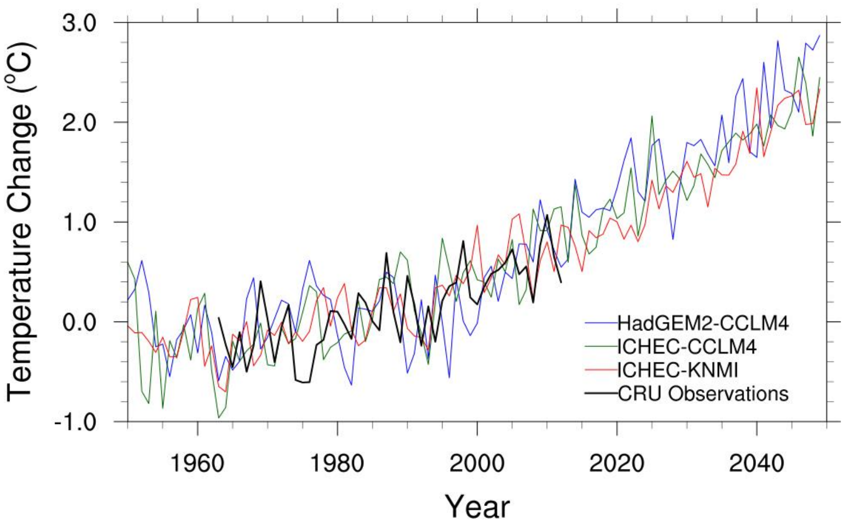


Figure 2.7

Time series of the change in West Africa annual average temperatures from the three CORDEX models analysed (see key). The model changes are relative to the average of the models in the respective domains from 1963 to 2000, while the CRU TS3.22 observational data (from 1963 to 2012) are relative to the observed 1963 to 2000 average.



Unlike rainfall, changes to temperature on the decadal time scale appear to be dominated by a systematic warming signal as opposed to multi-decadal variability. This can also be seen clearly when aggregating temperature changes over the region and analysing the time series' of model projections. Figure 2.7 shows the change in annual average temperature for the three model simulations, as well as the observed changes from the CRU dataset. All model simulations appear to capture the warming trend over the past 50 years and project a steepening of this trend in the future. By 2050, there is some uncertainty in the projected temperature change – even from a very small sample of simulations all driven with the same GHG forcing scenario – with the three simulations projecting a 2.1 to 2.8°C warming by 2050. The divergence of models would likely be much larger if additional simulations and forcing scenarios were included.

CHAPTER 3

Literature Review: Key Findings

Literature Review: Key Findings

3.1 Historical climate and impacts

A number of studies have investigated the impacts of past climate change on ecosystems and societal systems in West Africa. A recent review by Roudier et al (2014) analyses the impacts of climate in relation to water resources and agriculture. The review states that after two wet decades in the Sahel during the 1950s and 1960s, there has been a substantial rainfall deficit since 1970 (e.g. Paturel et al 2003). Roudier et al (2014) note that the region was exposed to particularly severe droughts in the 1973/1974 and 1983/1984 periods. Lebel and Ali (2009) suggest that while there has been a recovery of the rains in eastern parts of West Africa, there has been a continuation of drought conditions in western regions (which is consistent with the observed data shown in section 1.3).

In another recent review, Druyan (2011) draw on 10 climate and hydrological modeling studies and reach similar conclusions to Roudier et al (2014), commenting that the Sahel received considerable rainfall in the 1950s but this gave way to droughts in the 1970s that were most severe in the mid-1980s. The review notes that since the 1990s, seasonal rainfall accumulations over the Sahel have somewhat recovered, but not to the levels seen in the 1950s. The review also relates changes in rainfall to observed droughts and their impacts on society, finding that 100,000 people in the region died from starvation between 1972 and 1982, and in 1974 about 750,000 were totally dependent on food aid (UNEP, 2004).

A study investigating rainfall changes in Burkina Faso observed that key rainfall indices, averaged over 10 stations across the country, show a downward trend from 1961 to 1984 and an upward trend from 1985 to 1995 (Ibrahim et al 2014). The three driest years in the period 1961–2009 were 1977, 1983 and 1984 and in each year there was an annual rainfall deficit of more than 30% compared to the long-term average. However, the authors state that the mean dry spell length remained stable over the observational record despite significant changes in both the rainy season duration and the overall number of days with rain. Descroix et al (2013) find that rainfall variations in West Africa have led to strong fluctuations in river discharge with a generally negative trend from 1960 to 2010 but that in Guinean areas the decrease has been more moderate. Mahe et al (2013) stress the nonlinear relationship between rainfall and runoff in West Africa, noting that a 20% decrease in rainfall results in a decrease of 60% in runoff.

Sarr (2012) focuses on changes to climate in the semi-arid regions of West Africa. The study reports that since 1995 river and dam stream flows have increased markedly, while between 1966 to the early 1980s river flow was considerably less with only two major flood events occurring on average each year across the region. An earlier study by Sarr and Lona (2009) shows that in 2007, 2008 and 2009, several floods in West Africa caused severe destruction to infrastructure and crops, leading to extensive land erosion and degradation; in 2009 a flooding event in Burkina Faso led to a total of 9300 ha of cultivated fields being destroyed.

Diouf et al (2000) relates the length of the growing season to climate variability and change in the semi-arid regions of West Africa. The study finds that the growing season in the western Sahel (Senegal, Guinea Bissau and Mali) shortened during the latter half of the twentieth century.

3.2 Future climate and impacts

Future projections of climate in West Africa are uncertain and model projections provide contrasting evidence with regards to future impacts in the region. A range of crop models, hydrological models and other impacts models are used to determine the impact of climate change on agriculture, water resources, biodiversity and other key sectors in the region, but most studies require climate model projections that span a wide range of possible futures.

In Burkina Faso, Heubes et al (2013) investigated the potential impacts of climate change and land use change on the biodiversity of the region. Their study relied on a single very high resolution simulation (using the 0.1° resolution WorldClim dataset) so their results must be treated with caution. They conclude that the flora of Burkina Faso will primarily be negatively impacted by future climate and land use changes. However they also find that northern and southern regions of Burkina Faso are projected to benefit from an additional 100 mm of rainfall per year by 2050. The authors state that the positive effect of higher rainfall is more distinct in the arid Sahel than in the more humid regions of Southern Burkina Faso and might counterbalance the negative effect of increasing temperatures.

Ibrahim et al (2014) also examine changes to rainfall in Burkina Faso but use five different GCMs to conduct their analysis. Their findings differ from the Heubes et al (2013) study, as they show the number of the low rainfall events is projected to decrease by 3% while the number of strong rainfall events is expected to increase by 15 % on average. All five models project the rainy season onset to be delayed by one week on average and a consensus exists on the lengthening of the dry spells by approximately 20%.

According to the Sarr (2012) review, despite substantial model uncertainties, a delay in the onset of rainfall and a lengthening of dry spells is also projected for many other regions of West Africa. Although signals are mixed, a reduction in rainfall during the onset period has been projected for the future in some of the recent CORDEX simulations (Mariotti et al 2014). Other studies also find that the overall length of the rainy season may reduce in some parts of West Africa (e.g. Biasutti and Sobel 2009) with a risk of a reduction in the length of the growing period in the Sahel region (Cook and Vizy 2012).

A recent study by Ghile et al (2014) focuses on the Upper and Middle Niger River Basin to examine the impact of future climate change on river flows. The study uses the output of 15 GCMs from the CMIP3 and CMIP5 experiments to drive the “Mike” basin model, a GIS-based water resources system model. Their analysis of climate projections reveals no consensus in future trends of precipitation but all models project increases in temperature (mean change across the models of 2.1°C by 2050). They conclude that projections for the year 2030 indicate high probabilities of unacceptable minimum flows for Markala, the Mali-Niger border and Niamey, but that projections imply relatively low risks of unacceptable climate change impacts on the present large-scale infrastructure investment plan for the Basin.

Disagreement in rainfall projections in West Africa and across the Sahel is a common finding amongst a number of studies (Roudier et al 2014). The Druyan (2011) review finds some studies show unambiguous evidence of drying in the Sahel during second half of the 21st century with implications for increasing drought risk (e.g. Held et al 2005, Cook and Vizy 2006), while other studies project a wetter Sahel (e.g. Maynard et al 2002, Kamga et al 2005). Yamana and Eltahi (2013) examine the impacts of climate change on malaria transmission in

West Africa and find that the contrasting rainfall projections makes the future of vectorial capacity in West Africa highly uncertain. They analyze the output of 19 GCMs that show temperature increases between 2 and 6°C by the end of the 21st century but show that predicted changes in rainfall differ in their sign and range from a decline of 400% to an increase of 260%. However, despite this wide range the authors state that they do not expect to see a significant increase in malaria prevalence in the region over the 21st century.

CHAPTER 4

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